Project Abstract

Measuring and Increasing Complex Reasoning Performance in National Security Domains
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Introduction

The nation's security requires the continuous expansion of the problem-solving capabilities of its military and civilian defenders. The failure to prevent September 11 has often been called a failure of the imagination. How we respond to rapidly evolving threats to our security will increasingly require greater creativity and capacity to anticipate and analyze complex and interconnected situations and to craft robust solutions that exhibit strategic sense and wisdom. **This research is part of the quest to elevate human performance in the specific area of complex problem solving.**

National and USAFA Undergraduate Trends in Intellectual Development

King and Kitchener (1994) present findings suggesting that over the course of a college education, undergraduates, on average, start at a relatively low position (around stage 3) and do not progress significantly from there. This finding is consistent with the *Greater Expectations* report of the American Association of Colleges and University (AACU 2002), which prominently emphasized concerns that undergraduate education does not provide sufficient opportunities for college students to develop sophisticated and advanced critical thinking for the global information and technology age. These national concerns are of intense local interest at the US Air Force Academy (USAFA). On instruments such as the King and Kitchener's Reflective Judgment interviews, increases in stages of intellectual maturation between first and fourth year cadets were negligible. Administration of the *California Critical Thinking Dispositions Inventory* produced similar results. While USAFA's academic program is considered exemplary, it has not solved a problem challenging the broader postsecondary community, to significantly advance the intellectual maturity of undergraduates.

Goal and Objectives of This Exploratory and Education HSD Project

The main goal of this project is to produce more strategically capable problem solvers who can ably tackle complex scenarios in two contexts that loom large in national security and homeland defense: geospatial awareness and decision-making, and response to terrorist threats. A secondary goal involves advancing research in the cost-effective measurement of a key proxy of complex-problem-solving ability (intellectual development). Our instrumental, empirical, and theoretical objectives are to

- Use an established class of mathematics-rich problems, called model-eliciting activities (MEAs), to create a bank of scenarios appropriate for officer training
- Test and refine an experimental tool (Cogito®) for measurement of reasoning level

- Empirically explore the link between sustained effort in complex reasoning and intellectual development
- Ongoing refinement of the theory of intellectual ability by factors that affect problem solving cognition, including social dynamics of team problem solving, affect, creativity and wisdom

Social Dynamics in Problem-Solving

The collaborative social dynamics of team problem-solving extends well beyond the aggregation of skills from competent problem-solvers. Our conjecture is that engagement in team problem solving will deepen the reasoning skills of individual problem-solvers. In that regard, we pursue an interesting line of inquiry. The Perry and RJ scales produce scores for individuals rather than groups. Ironically, part of William Perry's original interests in formulating an intellectual development scale focused on an individual's capacity to integrate perspectives of others or external frames of reference. The analysis emerging from this study may help set the stage for analog measurements of a group's capacity to tackle a complex problem.

Scenario Domains

The table below describes some of the scenario areas that are appropriate for this project, in the two areas of geospatial awareness and terrorist network modeling. Because GeoBase is an operational concept across the Air Force, is adaptable outside of the Air Force, and integrates so many disciplines, it is a useful, real-world context for building scenarios.

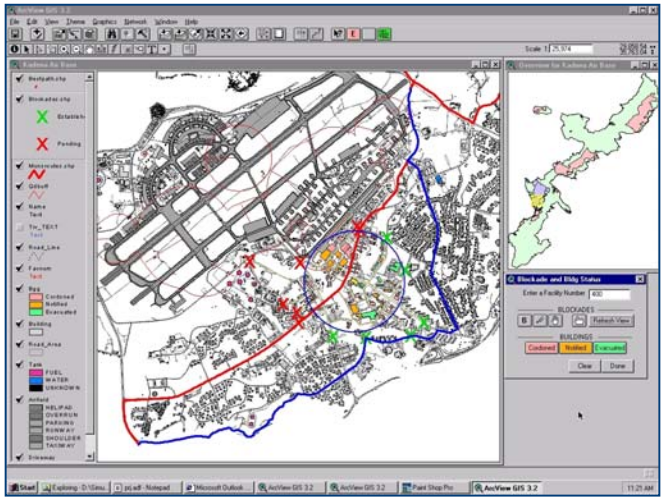

Figure 1: Sample "Smart Map" from Okinawa Base
Depicts and immediately updates geospatial decision-making variables. This particular simulation shows plume and cordon boundaries of a toxic gas leak.

Command of geospatial dynamics in a crisis or battle situation that is either anticipated or has arisen is an absolutely essential component of what the military refers to as the situational awareness. Command of those dynamics involves interpreting and integrating a complex array of variables from domains such as geology and geography, engineering, biology, chemistry and mathematics.

Violent Non-State Actor (VNSA) modeling

VNSA modeling involves the interdisciplinary application of tools and approaches from engineering design, systems theory, social behavior, and neuroscience to help understand how the complex social system that supports terrorist group formation evolves over time. These tools have been used to produce a systems level simulation tool that models of terrorist growth and recruitment. Initial development of VNSA modeling has been led by two of this project's Co-PIs (Casebeer and Bartolomei) and is promising. The model has been used to successfully

successfully retrodict (i.e. produce valid predictions concerning past events) the Sendero Luminoso terrorist activity in Peru. The underlying theory about the nature of terrorist organizations involves treating them as biological entities which change over time: such groups have a genesis point, grow, mature, and eventually transform. These processes occur at the intersections of environmental variables and facts about individual and group psychologies. VSNA is gathering fast-moving recognition as a significant tool in modeling the social network dynamics of the primary threats in the current national security and socio-political landscape.

Natural Disasters requiring humanitarian assistance, domestically or abroad • Hurricane , Typhoon, Drought, Tornado, Earthquake, Volcano • Off Base/On Base Fire (example: oil fields in Iraq and Kuwait) Attack on Air Base • Assets (e.g., Personnel, Aircraft, Airfield, Fuel Storage, Munitions, Storage, Water, Communications)	Terrorist Attack • Water Supply Poisoning • Synchronized Bombings • Chemical Attack • Anthrax or other biological agent attacks • Attack on upstream dam or reservoir (or general failure) • "Dirty Bomb" Nuclear Attack Military or Civilian Aircraft Crash

Examples of Contexts for Structuring GeoBase and/or VNSA related Problem Scenarios For This Project

What Performance Dynamics Are Expected To Emerge and Improve?

Lesh's Model Eliciting Activity (MEA) framework outlines some of the competencies that have been found to characterize successful problem-solving teams and that we expect will emerge and expand using the GeoBase and VNSA MEAs. Lesh and Lehrer (2003) have found that rather than simplify an overall task by the construction of a powerful representational tool highlighting aspects of a problem, the task pathways become deeper and more sophisticated because the problem solvers are able to dispense with its computational or surface structures. This is exactly the kind of modeling practice we hope to stimulate among cadets: **the capacity of a team to readily plumb the deep structure of a new and complex problem by rapidly crafting conceptual tools that dispense with its closer-to-the-surface layers.**

References

AACU (2002). Greater Expectations: A New Vision for Learning as a Nation Goes to College, Association of American Colleges and Universities.

Barron, B. (2000). "Achieving Coordination in Collaborative Problem-Solving Groups." The Journal of the Learning Sciences **9**(4): 403-436.

Barron, B. (2003). "When Smart Groups Fail." Journal of Learning Sciences **12**(3).

King, P. M. and K. S. Kitchener (1994). Developing Reflective Judgment. San Francisco, Jossey-Bass Publishers.

Lesh, R., M. Hoover, et al. (2000). Principles for developing thought revealing activities for students and teachers. The handbook of research design in mathematics and science education. A. Kelly and R. Lesh. Mahweh NJ, Erlbaum.

Lesh, R. and R. Lehrer (2003). Mathematical learning. Comprehensive handbook of psychology, Volume 7. W. Reynolds and G. Miller. New York, John Wiley.

Lesh, R., F. Lester, et al. (2003). A models and modeling perspective on metacognitive functioning in everyday situations where problem solvers develop mathematical constructs. Beyond constructivism: Models and modeling perspectives on mathematics problem solving, learning, and teaching. R. Lesh and H. M. Doerr. Mahwah, NJ, Lawrence Erlbaum Associates**:** 383-403.

Quesada, J., W. Kintsch, et al. (2002). A computational theory of complex problem solving using latent sematic analysis. Proceedings of the 24th Annual Conference of the Cognitive Science Society, Fairfax, VA, Lawrence Erlbaum Associates.

Zawojewski, J. and R. Lesh (2003). A models and modeling perspective on problem solving strategies. Beyond constructivism: Models and modeling perspectives on mathematics problem solving, learning, and teaching. R. Lesh and H. M. Doerr. Mahwah, NJ, Lawrence Erlbaum Associates**:** 317-336.

Project Website

http://erichamilton.net/research.htm